THE EFFECT OF A HIGH-INTENSITY INTERVAL TRAINING PROGRAM ON HIGH-DENSITY LIPOPROTEIN CHOLESTEROL IN YOUNG MEN

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ABSTRACT

Musa, DI, Adeniran, SA, Dikko, AU, and Sayers, SP. The effect of a high-intensity interval training program on high-density lipoprotein cholesterol in young men. J Strength Cond Res 23(2): 587–592, 2009—This study examined the impact of an 8-week program of high-intensity interval training on high-density lipoprotein cholesterol (HDL-C), total cholesterol (TC), and the atherogenic index (TC/HDL-C) in 36 untrained men ages 21–36 years. Participants were randomly assigned to an interval training group (n = 20) or a control group (n = 16). Participants in the experimental group performed 3.2 km of interval running (1:1 work:rest ratio) 3 times a week for 8 weeks at an intensity of 90% of maximal heart rate (~423 kcal per session). Results indicated significant pre- to posttraining changes in HDL-C (1.1 vs. 1.3 mmol L−1, p < 0.0001) and TC/HDL-C (3.8 vs. 3.1, p < 0.0001) but no significant changes in TC (3.9 vs. 3.8 mmol L−1, p > 0.05) with interval training. It was concluded that an 8-week program of high-intensity interval training is effective in eliciting favorable changes in HDL-C and TC/HDL-C but not TC in young adult men with normal TC levels. Our findings support the recommendations of high-intensity interval training as an alternative mode of exercise to improve blood lipid profiles for individuals with acceptable physical fitness levels.

KEY WORDS atherogenic index, cardiovascular disease risk, coronary heart disease, exercise training, total cholesterol

INTRODUCTION

HDL-C is considered the most potent independent risk factor for coronary heart disease (CHD) and is inversely correlated with CHD. High levels of HDL-C may have a protective role against coronary atherosclerosis (24) because of its role as a lipid scavenger involved in the reverse transport of cholesterol from the peripheral vascular compartment and tissues to the liver for excretion as bile. Though the mechanism for the beneficial roles of HDL-C has yet to be completely elucidated, it is thought that lecithin:cholesterol acyltransferase (L-CAT) and hepatic lipase (HL) facilitate the roles of HDL-C in reverse cholesterol transport from the arterial wall (20,33).

Endurance exercise training, characterized by continuous activity at moderate exercise intensity, demonstrates significant increases in HDL-C in both men and women after a period of training, typically 20–30% for endurance athletes compared with inactive controls (8,15). Furthermore, there seems to be a dose-response relationship between the amount of exercise performed and the increase in HDL-C (34) as well as the intensity of the exercise and increase in HDL-C (26). Despite the well-known benefits of aerobic training on blood lipid profiles, the effect of other modes of physical training on blood lipid profiles has not been adequately explored. Interval training, for example, which alternates between high-intensity work and periods of rest, is one of the most widely used methods of physical training in young men and women. Interval training studies using typical work:rest intervals (1:3 or 1:2.5) have shown little effect on blood lipid profiles (10,19,27), but it is not clear whether longer work intervals at high intensity, with prolonged periods of continuous physical activity, would have more favorable effects on blood lipid profiles.

The purpose of the present study was to determine whether an 8-week program of high-intensity interval training with a longer work:rest interval would significantly elevate HDL-C and reduce the total cholesterol (TC) and atherogenic index.
(TC/HDL-C) levels of untrained young adult men. If different modes of interval training can be shown to impact blood lipid profiles, this could suggest an alternative method of exercise to reduce risk of CHD.

**METHODS**

**Experimental Approach to the Problem**
The goal of this investigation was to compare the effects of high-intensity interval training on the lipid profiles of young men. The primary dependent variables in the study consisted of HDL-C, TC, and TC/HDL-C. Time to run 2.4 km (1.5 miles) was a secondary dependent variable to assess aerobic performance. All dependent variables were obtained at baseline and after an 8-week interval training intervention using high-intensity, prolonged periods of continuous activity (1:1 work:rest ratio).

**Subjects**
Forty-five apparently healthy men 21–36 years of age from a residential federal university population participated in the study and were randomly assigned to either an experimental (n = 23) or a control (n = 22) group before training. The research protocol was approved by the ethics review board of Bayero University, and all participants gave their written informed consent to participate in the study. All participants were physical education students, nonsmokers, had no cardiopulmonary or musculoskeletal diseases, and were taking no medications at the time of testing. None of the participants had participated in any organized exercise program for at least 6 months before the training program. All participants were asked to refrain from additional physical activities for at least 48 hours before the commencement of the training program and to maintain their nutritional habits. Participants in the experimental group had 3 training sessions per week throughout the 8-week period, which took place during the months of July and August. Participants missing 2 or more training sessions during the 8-week period had their data expunged from statistical analysis. The data for 9 participants–3 from the experimental group and 6 from the control group—were not included in statistical analyses, either because of incomplete data or noncompliance with the study protocol. Therefore, the data for 36 participants (experimental, n = 20; control, n = 16) were included in the analysis.

**Procedures**
On arrival at the laboratory, participants underwent a series of anthropometric measurements, including stature, body mass, and skinfold measures obtained from the chest, abdominal region, and front thigh in accordance with the protocol of the International Society for the Advancement of Kinanthropometry (13). Participants’ stature and body mass were measured using a portable stadiometer and an electronic scale to the nearest 0.1 cm and 0.1 kg, respectively. Skinfold thicknesses were measured on the right side of the body according to standard procedure (13). The sum of each participant’s skinfold measures was converted to percent fat using the data of Jackson and Pollock (14). Lean body mass (LBM) was calculated as the difference between fat mass and body mass.

A 1.5-mile (2.4-km) run was used as a performance test of aerobic fitness (1). Participants were instructed to run 1.5 miles (2.4 km) on a 400-m cinder track at the Bayero University Sports Complex. The time taken to complete the distance was recorded with a stopwatch. Verbal encouragement was given throughout the race to motivate participants. This same procedure was repeated a week after the training program.

**Blood Lipid Analysis**
All lipid measurements were carried out at the biochemistry laboratory of Bayero University. The pre- and posttraining venous blood samples were obtained from the participants between 8:00 and 10:00 AM after a 12-hour overnight fast and at least 48 hours after the last exercise session to prevent an artificial elevation of HDL-C from an acute exercise bout (28). A 10-mL syringe was used for blood sample collection using the procedure described by Bachorik (2). A tourniquet was tied around each participant’s upper arm to ensure a brief arrest of blood circulation to the forearm, and the participants were instructed to clench their fists to increase the prominence of the antecubital veins, from which blood was drawn. Blood samples (10 mL) were drawn from the antecubital vein of each subject under strict antiseptic conditions and were allowed to coagulate within 2 hours of venipuncture. Blood samples were stored in ethylene diaminetetraacetic acid collection tubes in a refrigerator until analysis. The serum was then analyzed within 4 hours for TC and HDL-C.

High-density lipoprotein cholesterol was determined using the phosphotungstic acid magnesium chloride (MgCl₂) method described by Lopes-Virella et al. (16). In this method, very-low-density lipoprotein cholesterol and low-density lipoprotein cholesterol were precipitated in serum by phosphotungstic MgCl₂, after which HDL-C was estimated in the clear supernatant. Total cholesterol was determined using the procedure described by Siedel (23). In the analysis, TC values were estimated enzymatically using commercially available assay kits (Boehringer, Mannheim, Germany). Coefficients of variation for HDL-C and TC were 4.2 and 1.6%, respectively. The ratio of TC to HDL-C was derived by dividing TC by HDL-C.

**Training Program**
In the training program, the experimental participants ran a distance of 3.2 km, 3 d-wk⁻¹, for 8 weeks. The control group was instructed not to undertake any vigorous exercise during the training period. Participants ran 4 sets of 800-m intervals (i.e., 4 × 800-m intervals, 1:1 work:rest ratio) at approximately 90% of their age-predicted maximal heart rate (HRmax) (220 – age). During the training program, each participant’s exercise heart rate (EHR) was periodically measured to ensure proper training intensity. Participants wore heart rate watches (model CE 0537, Polar Electro Company, Oulu, Finland) around their nondominant wrists,
and Polar electronic sensors designed to pick up heartbeat signals were worn around their chests. A thin film of Sigma electrode gel (Parker Laboratories Inc., Orange, NJ) was applied on the sensor shortly before each participant put on the monitor to facilitate conduction between the skin and the electrodes. The EHR monitoring was carried out to confirm the intensity of training. The EHR training data were downloaded via Polar Advisor Software and Polar Advantage computer interface. After each set of 800-m intervals, participants rested for the same period of time as the work phase, which amounted to a 1:1 work-to-rest ratio.

The workload for the experimental group (energy expenditure per exercise session) was estimated using the method of Heyward (11). The estimation of energy expenditure per exercise session was based on the assumption that a running velocity of 1.61 km in 10 minutes (9.6 km·h⁻¹, 6.15 min·km⁻¹) results in the expenditure of 10 METs. To calculate total energy expenditure, the MET value was converted to kilocalories per kilogram per hour by using the formula, 1 MET = 1 kcal·kg⁻¹·h⁻¹, and multiplying the value by the participant’s body mass in kilograms. Each interval training session lasted approximately 40 minutes and was performed at an intensity of 10 km·h⁻¹ (1 km in 6 minutes), for a total distance of 3.2 km. This amounted to an estimated energy expenditure of 423.2 kcal per exercise session, or approximately 1270 kcal·wk⁻¹. Each training session was preceded by a 10-minute warm-up involving stretching and calisthenics. Each training session was followed by an 800-m mild cool-down.

Before the commencement of training, a pilot study was performed to refine test administration procedures and determine the precision of the instruments used for data collection. Ten men undergraduate students ranging in age from 18 to 28 years were recruited for the pilot study. All measurements were taken once, and the Cronbach alpha coefficient was calculated to determine the reliability. For all dependent variables, alpha coefficients ranged from 0.761 to 0.894, indicating good internal consistency (18).

### Statistical Analyses

Data were analyzed using descriptive statistics (mean ± SD), independent samples t-tests, and paired samples t-tests. Changes in selected fitness parameters were determined by analyzing differences between pre- and posttraining values. Independent samples t-tests were used to examine between-group differences on the pretraining descriptive data. The pre- to posttraining differences for each group were tested with 2-tailed paired samples t-test. For hypothesis testing, the effect size was calculated as the difference in group means/pooled SD; the criteria used to characterize a small, moderate, and large effect size were 0.20, 0.50, and 0.80, respectively (4). All analyses were performed on an IBM-compatible computer using SPSS (version 10.0, SPSS Inc., Chicago, Ill). For all the analyses, a probability level of p ≤ 0.05 was chosen to indicate statistical significance. To protect against the possibility of type I error, a Bonferroni adjustment was used to evaluate the multiple paired t-tests evaluating the pre- to posttraining data on the 4 dependent variables for both groups. This adjustment resulted in a probability level of 0.006 (0.05/8) to indicate statistical significance.

### Results

The characteristics of participants’ anthropometric measures are presented in Table 1. There were no significant pretraining differences (p > 0.05) between the 2 groups.

Table 2 details changes in selected fitness parameters as a result of the training program. The only significant change observed was in distance run time (p < 0.0001) of the experimental subjects. There were no significant changes (p > 0.05) in body mass and body fat between the groups (Table 2).

Data on the effect of the 8-week training program on lipoprotein levels are presented in Table 3. A paired samples
Table 2. Changes in selected fitness parameters after training (n = 36).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Experimental (n = 20)</th>
<th>Control (n = 16)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>ABS Δ (%)</td>
<td>ABS Δ (%)</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>0.8 ± 1.3</td>
<td>0.8 ± 1.3</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>1.2 ± 15.8</td>
<td>−0.4 ± 5.0</td>
</tr>
<tr>
<td>2.4-km run time (min)</td>
<td>−1.1 ± 9.2</td>
<td>−0.3 ± 2.4</td>
</tr>
</tbody>
</table>

ABS Δ = mean absolute change. *p < 0.0001.

A t-test was conducted to evaluate the impact of the training program on the dependent variables. The experimental group showed significant changes at posttesting for 3 different variables. Significant increases were found for HDL-C (t(19) = 6.087, p < 0.001; effect size = 0.30). Significant decreases were found for distance run times (t(19) = 5.535, p < 0.0001; effect size = 0.52) and TC/HDL-C at posttesting (t(19) = 4.666, p < 0.0001; effect size = 0.34). The effect sizes of 0.30, 0.52, and 0.34 for these 3 dependent variables revealed only a small to moderate effect of interval training on these variables. Total cholesterol did not show any significant change at posttesting (t(19) = 0.557, p = 0.584; effect size = 0.15). For the control group, none of the 4 variables showed any significant change (p > 0.05) at posttesting. Details of the results can be found in Table 3.

Discussion

The results of this study suggest that 8 weeks of high-intensity interval training can elicit favorable changes in HDL-C and the lipoprotein ratio in young adult men. Specifically, we observed an 18% increase in HDL-C, similar to increases previously reported with endurance training, but there was no change in TC. These findings are in agreement with aerobic exercise training protocols in adults and adolescents (17,21,30), but they differ from those of previous interval training studies (8,19,27,28). We also observed a 9% increase in aerobic performance (as measured by 2.4-km run time).

It has been suggested that endurance training protocols using energy expenditures equivalent to 1000–1200 kcal·wk⁻¹ can result in significant increases in HDL-C levels (9,20,29). The literature also suggests that high-intensity aerobic exercise facilitates favorable changes in HDL-C compared with low-intensity exercise (26). In the present study, the experimental group expended an estimated 1280 kcal·wk⁻¹ and trained at very high intensity (90% HRmax). Although these factors could have contributed to the observed improvements in HDL-C and the atherogenic index, a previous interval training study with similar training intensity and caloric expenditure did not show increases in HDL-C or improved blood lipid profiles (27). However, shorter interval lengths (1 minute; 1:3 work:rest) could have been a contributing factor (27).

It is plausible that longer continuous intervals at high intensity may be necessary to improve HDL-C and atherogenic index. Data from the spinal cord literature reveal that high-intensity arm cranking (up to 80% HRmax) for longer continuous intervals (3–4 minutes) results in significant increases in HDL-C and decreases in TC/HDL-C compared with low-intensity interval arm cranking (40–60% HRmax) (5,12). In the present study, the typical interval length for the 800-m run was between 4 and 5 minutes at very high intensity. Interestingly, Thomas et al. (28) used a similar running protocol (4-minute interval lengths [1:1 work:rest] at 90% HRmax) but failed to show changes in HDL-C or TC in young men. However, higher baseline HDL-C levels in the Thomas et al. (28) study might suggest a more physically active cohort and may have created a ceiling effect with less

Table 3. Pre- and posttraining blood lipids and aerobic performance scores of participants (n = 36).

<table>
<thead>
<tr>
<th>Test</th>
<th>Experimental (n = 20)</th>
<th>%Δ</th>
<th>Control (n = 16)</th>
<th>%Δ</th>
</tr>
</thead>
<tbody>
<tr>
<td>HDL-C (mmol·L⁻¹)</td>
<td>Pre 1.1 ± 0.3</td>
<td></td>
<td>Post 1.3 ± 0.4</td>
<td>18.1*</td>
</tr>
<tr>
<td>TC (mmol·L⁻¹)</td>
<td>Pre 3.9 ± 0.7</td>
<td></td>
<td>Post 3.8 ± 0.8</td>
<td>−2.0</td>
</tr>
<tr>
<td>TC/HDL-C</td>
<td>Pre 3.8 ± 0.8</td>
<td></td>
<td>Post 3.1 ± 1.0</td>
<td>−18.1†</td>
</tr>
<tr>
<td>2.4-km run time (min)</td>
<td>Pre 11.9 ± 0.8</td>
<td></td>
<td>Post 10.8 ± 0.9</td>
<td>−9.2†</td>
</tr>
</tbody>
</table>

All data are presented as mean ± SD. HDL-C = high-density lipoprotein; TC = total cholesterol; TC/HDL-C = total cholesterol to high-density lipoprotein ratio. *p < 0.001; †p < 0.0001.
room for HDL-C increases. The more unfavorable baseline concentrations of HDL-C in our subjects may have allowed for greater increases with training and contributed to the significant improvement (18%) over the intervention period, which has been observed previously (15).

It was not surprising to observe that TC did not change significantly with training, given that exercise produces reciprocal changes in TC, especially with regard to HDL-C and low-density lipoprotein cholesterol (LDL-C). In most studies, as HDL-C increases, LDL-C decreases, and this leads to either no change or a slight reduction in TC (7,9). Furthermore, because the subjects in the present study had favorable pretraining mean TC levels, there was less room for further reduction in cholesterol levels (19,32).

Although public health trends emphasize low to moderate physical activity for the purpose of CHD risk reduction, the high-intensity interval training used in this study may be recommended as an alternative mode of exercise for individuals with acceptable physical fitness levels. The present study provides evidence that interval training exercise can improve HDL-C and the atherogenic index, which could have a significant public health impact by reducing CHD risk.

It has been hypothesized that a 1% reduction in TC is associated with a 2% reduction in risk for CHD, and, for a 1-mmol-L⁻¹ increase in HDL-C, there is a corresponding 2–3% reduction in the risk for CHD for men and women (15,22). It also has been hypothesized that for every unit drop in TC/HDL-C, the risk of CHD decreases 53% (25). On the basis of these hypotheses, the increase in HDL-C as a result of interval training noted in this study could potentially lead to an 18–27% reduction in heart disease risk in active participants. Similarly, the drop of 0.7 in the atherogenic index could potentially lead to a reduction of about 37% in CHD risk. It is interesting to note that other studies have shown that high-intensity exercise had a favorable impact on metabolic function in older women (improved insulin resistance), which lends further support to the use of higher-intensity modes of training throughout the lifespan (6).

Several limitations of this study should be considered when interpreting the results. Although interval training lowered HDL-C and the atherogenic index, we could not control for external factors such as alcohol consumption and diet, any of which could have affected TC and its subfractions (21). Clearly, these external factors should be controlled in future studies. In addition, our estimates of energy expenditure during training sessions were obtained during field testing, which may have demonstrated less accuracy than measures obtained in the laboratory.

**Practical Applications**

The results of this study indicate that high-intensity interval training using prolonged, continuous periods of activity (1:1 work:rest ratio) is capable of elevating HDL-C and reducing the atherogenic index in young adult men with normal TC levels, but such training seems to have no effect on TC. Although our results cannot be generalized to high-risk populations, the findings from the present study do have some clinical implications for young adult men with normal TC and less favorable HDL-C levels. Research has shown that even in healthy men with slightly elevated TC, further lowering of TC reduces the risk for a first-time major coronary event by 37% (3). Future studies should examine whether healthy participants with higher baseline cholesterol levels can use high-intensity interval training protocols with a similar work:rest interval to increase HDL-C and, possibly, lower TC.

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